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ABSTRACT

The interactions of three factors that may be involved with the memory for pattern or sequence in visual materials were investigated in this study: (1) arbitrariness of representation; (2) task; and (3) ability of students. The subjects, who were 29 graduate students in education, were pretested for general ability and randomly assigned to four groups. Students studied a series of four maps which were arranged in order of increasing complexity from eight to 20 elements; these elements were shown either as pictures or as squares and were numbered from left to right and from top to bottom. The subjects were required to either list the elements in sequence or to draw the overall pattern. It was found that, although the scores generally declined as the number of elements increased, the results were significant for task (list or draw) and task by map (number of elements) interaction. A correlation was also found between one of the maps and the pretest. The implications of these findings for instructional design are that when seven or more elements are presented in maps, difficulties may result when students are asked to perform a successive task. On the other hand, when the task calls for simultaneous processing, access to a chunking strategy will enable students to compensate for the numerous elements. Supporting data for the study are presented in seven tables, and a list of 22 references is provided. (MES)

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The Effect of the Number and Nature of Features and of General Ability on the Simultaneous and Successive Processing of Maps

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Running head: The Effect of the Number and Nature of Features

ABSTRACT

Twenty-nine graduate students studied a series of four maps. Elements in the maps were shown either as symbols or squares. Each element was labeled and numbered from left to right, top to bottom. Subjects were required to either list the elements in sequence or draw the overall pattern. Findings were significant for number of elements in the map, task, and task by map interaction. A correlation was also found between one of the maps and the pre-test. Conclusions were drawn as to processing strategies utilized by participants and implications for design of educational materials.

INTRODUCTION

Graphics in text add a unique dimension to communication in educational materials. They afford a bridge between pictures and text which the learner may use for more complete understanding than through either text or pictures alone. They can be constructed with varying degrees of verbal embellishment, allowing application throughout a broad spectrum of student abilities.

Graphics include a spatial dimension which is unavailable in text-only materials. On the other hand, materials which are strictly pictorial do not allow the learner to integrate language along with the image. Not only are the graphic images themselves subject to variation, but the layout into which they are assembled can also take many forms. Fleming and Levie (1978) refer to a kind of syntax unique to graphics. Word and image used together reinforce each other, appealing to both verbal and visual memories.

There is some evidence that varying the amount and type of detail in elements of a graphic layout may effect the memorability of the layout itself. Winn (1986a) studied students' abilities to list (in order) or draw a pattern of electronic components in circuit diagrams with differing amounts of detail. He found that more detail appeared to aid memory in the list task, but detracted from memory for spatial relationships (drawing). On the other hand, less detail aided memory for drawing elements in relation to each other, while it interfered with ability to remember a list of components.

Amlund, Gaffney and Kulhavy (1985) found that map-featured information was better recalled than nonfeatured information by all groups in two experiments they conducted to investigate validity of the conjoint retention hypothesis (that independent coding of spatial and semantic information facilitates recall). That study suggested that familiar symbols are superior to unfamiliar symbols.

Graphics can be processed two different ways. First, they can be interpreted sequentially. Although the whole layout may be visually available, viewing the information may dictate processing in a sequential manner, either due to the logic within the information being presented (start to finish) or to the task required afterward. Wholistic interpretation is a second possibility. In order to grasp a systemic process where there is no beginning and no end (as in a diagram showing biological cycles), mentally assembling parts together to form an integrated whole is an absolute necessity for comprehension of the message. Or wholistic integration may be required by any of a number of other tasks.

Simultaneous and successive processing have emerged within the past decade as parts of investigation into relationships among various aspects of learning, including reading, composition, graphics and education of the handicapped. Simultaneous processing is defined by Das (1979) as "the synthesis of separate elements into groups, these

groups often taking on spatial overtones". Successive processing, on the other hand, refers to "processing information in a serial order". Das makes the distinction that simultaneous processing deals with objects that are "at once surveyable" while successive processing deals with those "not totally surveyable".

Based in neurology, simultaneous and successive processing are not located in specific brain centers, but are the result of the interaction of higher level cortical areas. A large portion of research (Das, 1978, 1979, Kirby & Das, 1977, Luria, 1966, 1973) has involved establishing the validity of the two constructs (simultaneous and successive processing), by the administration of series of tests and factor analytic techniques. The tests included Raven's Progressive Coloured Matrices, Figure Copying and Memory for Designs (simultaneous) and Digit Span, Visual Short-term Memory and Serial or Free Recall (successive). Other researchers have been studying factors that correlate with successive and simultaneous ability as measured by these tests (McRae, 1986, Wachs and Harris, 1986). Still others (Amlund, Gaffney and Kulhavy, 1985, Winn, 1986) have designed special materials for investigating simultaneous and successive processing by performance of designated tasks.

Research on Simultaneous and Successive Processing

Simultaneous and successive processing were explored in the work of Russian neurologist A.R. Luria. Luria (1966, 1973) found difficulty in simultaneous processing among patients with lesions in the left parieto-occipital lobe. He noted that these patients could not integrate visual or tactile stimulation into simultaneous, spatially organized groups. Successive processes appeared intact. Patients with damage in the fronto-temporal lobe, on the other hand, were not able to integrate motor and acoustic stimuli into successive, serially organized groups.

Das investigated simultaneous and successive processing (Das, Kirby, & Jarman, 1978, Das, Che & Williams, 1979, and Das, 1983) on the basis of Luria's work, including educational applications with the handicapped. He suggests that it is most appropriate to conduct instruction with students through that processing ability which is more intact and to teach strategies which can then be used by the student in processing academic information. Das feels that learning-disabled students did not succeed in processing materials as well as "normals" (Das, Che & Williams, 1979) due to a lack of ability to choose the appropriate strategy. In another study (Kirby & Das, 1977) it was found that those students who were able to process material better, both simultaneously and successively, were also able to read better. Again, Das attributed this to having a choice of strategies available. In both studies the students were comparable in regard to I.Q.

McRae (1986) investigated the relationship between simultaneous/successive processing and word recognition/comprehension in reading of primary grade children based on Das's work. McRae found

indications of a relationship between simultaneous processing and reading comprehension.

Wachs and Harris (1986) looked at simultaneous and successive processing in relation to math and composition abilities, also based on Das's work. Significant correlations were found between simultaneous processing and SAT math scores. Significant correlations were also found between successive processing and grades in an introductory English composition course, supporting the Das-Luria model. Wachs and Harris believe that simultaneous/successive processing contributes to academic performance in college students.

Application in Research on Graphics

Winn (1980, 1981, 1982, 1983) has investigated various aspects of graphic communication, finding that the manner of visual presentation makes a difference in learning and retention. Subsequently, he took the Das-Luria model farther than most researchers in that he utilized graphic instructional materials in his studies rather than the usual test materials used in work by Das and other researchers. Winn has used simultaneous/successive processing to interpret some of his data, and to formulate hypotheses tested in later studies (Winn, 1986a, 1986b).

The study reported here investigated the interactions of three factors indicated in Winn's previous studies which may be involved with memory for pattern or sequence in visual materials, specifically, the interactions among 1) arbitrariness of representation, 2) task, and 3) ability of students. The earlier study found that representing electronic components as symbols, as opposed to squares, interfered with student ability to recall the pattern the elements formed. In contrast to Winn's study with electronic circuit diagrams, symbols selected for this study were realistic pictures. Like the circuit diagram study, symbols were laid out on a grid structure (previously as circuit diagrams, now as maps), and squares were used for the alternate symbol system. Treatment and task were both similar to the previous study. It was expected that treatment (study of pictures or squares) would interact with task (draw or list elements). It was also expected that performance on both tasks would decrease with an increase in the number of elements per map, due to short-term memory limitations (approximately seven elements; Miller, 1956). The sequence task, requiring successive processing, doesn't allow use of the "chunking" strategy (remembering a cluster of elements as one group) which is available in simultaneous processing (Das, et al., 1979). Basic ability of the subjects, measured by Raven, was also expected to play an important role in memory for sequence and pattern as difficulty increased.

METHOD

Subjects

Subjects participating in the experiment were twenty-nine graduate students in Education. They were randomly assigned to each of four groups.

Design

The design of the study was a two by two by four factorial, with task (list vs. draw) and treatment (pictures vs. squares) as between subjects factors, and map (8, 12, 16, 20 elements) as a within subjects factor. The dependent variable was the number of elements either 1) listed in the correct order (successive task) or 2) drawn correctly relative to other elements (simultaneous task).

Materials

Two versions of four maps were prepared, one version with small pictures of locations in a city, and another with squares in these same positions. Each corresponding element (realistic picture or square) was identified with the same word ("store", "factory", "bridge", etc.). Each symbol and accompanying word was numbered, left to right and by rows, from top to bottom. Four levels of each map included eight, twelve, sixteen and twenty elements each.

Packages received by subjects comprised a cover sheet with instructions, followed by four maps separated by blank sheets of paper. After studying each map, the required task (list or draw) was completed on the next blank sheet of paper. Maps were in order of increasing complexity.

Procedure

Sets D and E of Raven's Progressive Matrices were administered to all subjects in order to assess their general ability.

A week later, at the treatment session, materials were randomly distributed. Subjects who received the sequence packets were tested

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TABLE 1 ABOUT HERE
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in a different room than those who received the pattern packets. In an earlier study (Winn, 1986a), a ceiling effect was found for the sequence group when the test period lasted three minutes. In this study, the time limit for the sequence task was lowered to avoid this, while time for the pattern task was not changed, necessitating separate testing areas.

The sequence group had one and a half minutes to study the maps, and one and a half minutes to list the elements in order. The pattern

group had three minutes to study the maps and another three minutes to draw the pattern from memory. Instructions were for subjects to depict location of each element, in the form of a square, regardless of whether they had studied pictures or squares. They were asked not to label or number their drawings.

Maps were studied, and drawn or listed, in order of increasing complexity, beginning with the eight element map and ending with the twenty element map.

Scoring

In scoring the sequence task, one point was given for each element listed in the correct order. If an element was missing, but others were in the correct order, credit was given for all parts sequentially listed. Scoring for the pattern task was more difficult. Because of the variability in accuracy with which the subject drew the diagrams, scores were based on the relative rather than absolute placement of elements. Each map was scored by three people. Final scores were an average of the three evaluations.

Raw scores were converted to percentages because the number of features on the four maps were not equal. Two by two by four repeated measures analysis of variance was performed. Task and treatment were between subjects factors, map was a within subjects factor. In the event interaction between map and either task or treatment were significant, separate two by two analyses of variance were planned. Interactions between map scores and results of Raven's matrices were analyzed using multiple regression.

RESULTS

Means and standard deviations for each of the four maps are shown in Table 2. There were no significant findings for treatment or

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TABLE 2 ABOUT HERE
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task, nor for the task by treatment interaction. However, significant differences were found for map, $F(3, 75)=20.5$ $p<.001$ and for the task by map interaction $F(3, 75)= 15.7$, $p<.001$.

Scores generally declined as the number of elements increased.

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TABLE 3 ABOUT HERE
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Percentages of correct scores declined steadily for the sequence task. They initially declined in the pattern task, but then they levelled off, and rose again.

Two-way factorial analysis of variance for each map separately revealed some significant differences for the eight element map. Subjects in the sequence task group scored higher than subjects in the pattern task group. For task, $F(1, 25)= 10.3$, $p<.01$. Scores are shown in Table 4.

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TABLE 4 ABOUT HERE
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For the task by treatment interaction, $F(1, 25)=3.99$, $p=.06$, scores are shown in Table 5. Subjects who drew patterns after studying

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TABLE 5 ABOUT HERE
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pictures performed considerably better than those who drew patterns after studying squares. Viewing pictures or squares made no significant difference in performance when listing the elements. Analysis of simple main effects, showed the two means for the pattern task to be significantly different, $F(1,12)=6.40$, $p<.05$.

No significant main effects were found for the 12 or 16 element maps. However, on the twenty element map, task was significant, $F(1, 25)=20.78$,

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TABLE 6 ABOUT HERE
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$p<.001$. Scores for the pattern task were significantly higher than the scores for the sequence task, the opposite of findings on the eight element map.

Multiple regression revealed a significant interaction, $F(7, 21)=$

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TABLES 7 & 8 ABOUT HERE
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2.4, $p=.058$, between the pattern and sequence tasks with Raven scores as a predictor for the twenty element map. The interaction was ordinal, and indicated that Raven scores could predict performance on the sequence task but not on the pattern task.

DISCUSSION

Subjects who were part of the sequence group were unable to retain more than approximately seven items, as predicted by research (Miller, 1956). Although percentages declined over maps, this served as more of a reflection of the increase in the number of elements per map than of

an inability to succeed on the part of the participants. In fact, mean scores per map were, in order, 7.54, 8.70, 8.82 and 9.27, all above the standard seven.

Scores on the pattern task did not follow the same profile. While percentages initially declined, they flattened out and then rose again as the number of elements increased. Participants may have used a chunking strategy, combining several elements into one unit of memory, to extend the total number of elements retained. It appeared that the twenty element map either allowed the greatest opportunity for chunking or forced the participants to resort to it. The percentage remembered was nearly as high on the twenty element map as it was on the map with eight elements. Mean scores per map were 6.21, 7.50, 10.14 and 15.43. The eight element map was easier for participants remembering the elements in sequence. In contrast, chunking strategies made the twenty element map easier to recall for those trying to remember elements they surveyed simultaneously. An examination of the maps with 12 and 16 elements revealed patterns that were not as easy to cluster.

Dependency of performance on the number of elements in a map also extended to the differential effects of task and treatment. The interaction of task with treatment, involving only the eight element map, was contrary to what was expected on the basis of Winn's (1986) circuit diagram studies. It had been expected that adding detail to the elements would make it easier for students to perform on the sequence task but would not aid in the pattern task. In fact, students who studied pictures scored higher on the pattern task than those who studied squares. This supports Amlund, Gaffney and Kulhavy (1985) who found greater memorability for maps with pictures than other symbols. In contrast to Winn's electronic diagram study, symbols used in this study were familiar (house, church, etc.), while symbols in the earlier study were abstract and unfamiliar. Kulhavy, Schwartz and Shaha (1983) have reflected on the possibility of unfamiliar symbols actually interfering with learning.

Another example of how the number of elements affected performance is found in the relationship between task and student ability. When the task became most difficult (the twenty element map) an aptitude treatment interaction showed that low ability students performing the sequence task had the greatest difficulty. Performance on the pattern task was not affected by ability. There was no difference on either task for high ability students. This indicates that while ability may be necessary for good performance on the sequence task, use of a chunking strategy compensated for low ability on the pattern task.

This study has shown that performance on simultaneous and successive processing of maps is determined more by the number of elements per map than by the amount of detail in its elements. The value of graphics to communicate information by spatial layout is supported by the contribution of a chunking strategy during simultaneous processing which is not available in the sequence task requiring successive processing.

Interaction of task and treatment, in contrast with the earlier circuit diagram study, suggests a need to consider familiarity of elements along with task, amount of detail and student ability. Also suggested is a need for further studies in which familiarity as well as complexity of details in elements in graphics is varied.

Indications for education are that when more than seven elements are presented in maps, difficulties may result when students are required to perform a successive task. On the other hand, when the task calls for simultaneous processing, access to a chunking strategy will enable students to compensate for the numerous elements. This supports Das (1978, 1979, Kirby & Das, 1977) when he observes that teaching chunking strategies to students may increase their abilities to remember elements in visual materials.

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Table 1 Summary of Maps and Tasks

	Group 1	Group 2	Group 3	Group 4
TASK	sequence	pattern	sequence	pattern
MAP	realistic w/labels	realistic w/labels	squares w/labels	squares w/labels
NO. OF ELEM.	8, 12, 16, 20	8, 12, 16, 20	8, 12 16, 20	8, 12 16, 20

Table 2

Mean Percentages of Correct Items by Map.

(Standard Deviations in Parentheses)

No. of elements	Squares		Pictures	
	Sequence	Pattern	Sequence	Pattern
8	96.43	69.94	92.19	85.71
	(9.45)	(14.17)	(11.45)	(18.30)
12	67.86	54.76	77.08	70.24
	(31.71)	(15.11)	(17.68)	(12.60)
16	50.89	63.39	59.38	63.39
	(16.31)	(17.83)	(14.17)	(15.91)
20	46.43	69.29	46.25	85.00
	(25.61)	(10.58)	(20.13)	(12.58)

TABLE 3 Scores per map

MAP	8	12	16	20	
sequence	94	73	55	46	%
pattern	78	63	63	77	%

TABLE 4

EIGHT ELEMENTS

TREATMENT	TASK: draw	TASK: list	
pictures	85.7	92.2	88.95
squares	69.6	96.4	83.0
	77.65	94.3	averages

TABLE 5

INTERACTION

TREATMENT	TASK: pattern	TASK: sequence	
pictures	76.1	68.7	72.2
squares	64.3	65.4	64.8
	70.2	67.2	averages

TABLE 6

TWENTY ELEMENTS

TREATMENT	TASK: pattern	TASK: sequence	
pictures	85.0	46.2	65.6
squares	69.2	46.4	57.8
	77.1	46.3	average

Table 7

Statistics for Interaction of Ability with Task

	Unstandardized Regression Coefficient	Y Intercept
Sequence	4.99	-44.12
Pattern	.20	73.60
Maximum and minimum slope of Ya-Yb with 95% confidence interval	7.06 and -2.51	

R squared	Change in R squared	MS residual	F	p
.602	.089	256.93	5.65	<.05

TABLE 8 RAVEN'S SCORES GENERALLY CORRELATED WITH MAP SCORES